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Station Test of Champaign Power Plant

Elec. Engineering
B. S.
1904

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STATION TEST OF CHAMPAIGN POWER PLANT

BY

WILLIAM HARRY WEHMEIER

FRANK WYMAN HILLIARD

THESIS

FOR THE

DEGREE OF BACHELOR OF SCIENCE

IN

ELECTRICAL ENGINEERING

IN THE

COLLEGE OF ENGINEERING

UNIVERSITY OF ILLINOIS

PRESENTED JUNE, 1904

UNIVERSITY OF ILLINOIS

May 27, 1904 190

THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

FRANK WYMAN HILLIARD and WILLIAM HENRY WEHMEIER

ENTITLED STATION TEST, CHAMPAIGN POWER PLANT

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE DEGREE

OF Bachelor of Science in Electrical Engineering.

Morgan Brooks

HEAD OF DEPARTMENT OF Electrical Engineering.

66170

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P R E F A C E

The following tests on the Champaign and Urbana Gas, Railway and Electric Co.'s power plant were made for the purpose of determining the Unit Efficiency, Cost of Coal per Kilowatt Hour output, Total Power Output and Relative Distribution over the Feeders, on an average day when plant was operating under normal conditions.

A delay was caused by waiting for the completion of a high tension line which was not put into operation until about May 1, 1904, so that only two tests were made, the first for the Cost of Coal per Kilowatt Hour output, the Unit Efficiency and to determine the Relative Distribution of Power over the Feeders. The second test was merely a run on the total output including both D.C. and A.C. sides, and a check on the unit efficiency.

Thanks are due to Messrs.J.L.Buchanan, C.E.Mead, B.French, A.C.Foster, A.B.Shipman and the employees of the power plant for their hearty cooperation and assistance in the test.

C W Hoelscher

F. W. Hilliard

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C O N T E N T S

1. STATION

a. Location

b. Equipment

c. Use.

2. TESTS

No.1. Distribution, Cost of Coal per K.W.H. Unit Efficiency.

a. Results.

b. Discussion.

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a. Results.

b. Discussion.

3. CONCLUSIONS.

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STATION

The plant is located near the crossing of the Illinois Central and Big Four Railroad tracks and is on a switch connecting the two roads.

Originally it was a city lighting plant, all street car service being horse power, but in 1890 the electric system of traction was installed. Since the original installation of electric railway generators several changes and additions have been made. For a number of years previous to 1904 the load was carried by two Westinghouse Railway Generators of 150 and 110 K.W. capacity respectively. When the Danville, Urbana and Champaign Interurban line was put into operation the load was found to be too heavy for the two generators then in use and in the spring of 1904 a direct connected 500 K.W. Double Current Generator was installed. This machine alone being capable of carrying all the city car load and also the Alternating Current Side was used to supply power to the sub-station at Fithian, which is about seventeen miles east of Urbana on the Interurban line.

During the day this 500 K.W. Generator is the only one in the plant which is run. The day lighting service is supplied by a 45 K.W. Westinghouse Alternator driven by a 54 H.P. 500 volt motor. Besides the above mentioned apparatus the plant contains the following equipment:

One Rankin and Fitch Corliss Engine 18" x 36" rated at 225 H.P. belted to a 150 K.W. Westinghouse 500 volt six-pole railway generator.

One Porter Allen 16" x 16" 200 H.P. engine belted to a 110 K.W. Westinghouse 500 volt railway generator.

One Russell 14" x 20" 205 H.P. engine belted to three 50 light Western Electric Arc Machines.

One Ideal 18-1/2 x 18, 300 H.P. engine belted to one 150 K.W.Wood Alternator 133 cycles and one 40 light Western Electric Arc machine.

One 14 x 14 Ideal 125 H.P. engine belted to a 55 K.W. Westinghouse Alternator.

The unit on which the test was made consists of a 30 x 30 Russell single expansion non-condensing 750 H.P. engine direct connected to a 500 K.W. General Electric Double Current Railway Generator. Rating 833 amperes, 600 volts.

The boiler house equipment consists of the following:

One Aultman and Taylor 260 H.P.Boiler.

One battery of 2 B.&W. Boilers, 237.5 H.P. each.

One B.&W. Boiler 275 H.P.

One Battery of two Sterling Boilers 260 H.P. each.

All of the above boilers are operated at 120 lb. steam pressure above atmosphere.

The following pumps are in service:

One Dean Duplex Pump 7 x 4 x 10.

One Gardner " " 7 x 4 x 10

One Buffalo " " 6 x 4 x 6

One Blakesley Pump 14 x10 x 14

A new switchboard has been installed during the last year consisting of nine panels, five feeder panels, two generator panels, one total output and one high tension panel. Each feeder panel is equipped with one Keystone 0-1000 ammeter, one Westinghouse circuit

breaker and one single throw single pole feeder switch. The 110 and 150 K.W. generator panels each have one Keystone 0-1000 ammeter, one Westinghouse circuit breaker, one single pole, single throw switch and one field switch. The 500 K.W. Generator panel has one Thompson Astatic 0-1500 ammeter, one General Electric circuit breaker, one single pole single throw switch, one field switch, one Thompson Integrating Wattmeter, 1200 Amperes, 600 volts. The high tension panel contains one General Electric Power Factor Indicator, one Thompson 0-1200 ammeter, one 0-500 voltmeter, one Thompson Integrating Induction Wattmeter. The station voltmeter is secured on an arm at the end of the switchboard. A G.E.Co. oil switch is used on the low tension side of the three-phase transmission; capacity 1500 amperes, 600 volts. Current transformers with a ratio of 300 to 1 are used in connection with the ammeter and wattmeter.

The transformers used for stepping up on the high tension transmission line are three 150 K.W. 370-15000 volts General Electric Transformers. Both sides are connected in delta.

The station furnishes light to the town of Champaign, power to the Champaign and Urbana Street Railway, and also power to the Danville, Urbana and Champaign Interurban Company, which operates between the towns of Danville, Urbana and Champaign.

The incandescent lighting circuits are operated day and night. The city street lighting is operated only on dark nights and then all night. Power is in service from 5:30 A.M. to 12 P:M. except when cars are run after the midnight hour to accomodate dancing parties etc.

TESTS

Test No.1.

The first test was made on April 18, 1904, for the purpose of finding the general distribution on the various feeders, the cost of coal per kilowatt hour and the unit efficiency. The day chosen was one of average operating conditions. The test was run from 7:30 A.M. to 5:00 P.M. Readings of current and voltage were taken every minute. One man was stationed at each of the five feeders, one at the total ammeter, and one at the station voltage, so that simultaneous readings were obtained. Indicator cards were taken from the Russell Engine by means of Crosby indicators every five minutes. The coal and ashes were weighed throughout the test and weights carefully recorded and corrected for moisture. An average of the ammeter and voltmeter readings was found for every fifteen minutes and curves plotted showing each feeder distribution in kilowatts. These distribution curves are shown on plates Nos. VII, VIII and IX.

Plate VI shows curves of total current, voltage and watts for the day, the data for these curves being shown on plates I and II.

A graphical representation of the feeder consumption is shown on plate No.V. The power feeder required the greatest number of kilowatt hours, next the east side, then the Urbana feeder, and D.U.C. feeder, and last the West Side feeder.

The following table shows the average values of kilowatts indicated and current, and also shows the relative values of distribution.

Feeder	Average K.W.	I.	Ratio	% Total
West Side	21.8	37.	1.00	11.12
Urbana	38.1	65	1.75	19.46
D.U.C.	38.1	65	1.75	19.46
East Side	46.9	80	2.15	23.94
Power	50.9	86	2.33	26.02

Tables from which the above were obtained are given on plates Nos. III and IV.

Station Wattmeter Correction.

The accuracy of the wattmeter of the D.C. side of the system was doubted and this test No. 1 affords an excellent check on the meter readings. Current on the total ammeter and each feeder ammeter was read every minute, also the station voltage.

The kilowatt hours were calculated both for the total ammeter readings and for the sum of the feeders, and results compared with the wattmeter indications for the day.

K.W.H. calculated from total ammeter, 1887

K.W.H. " " sum of feeder readings 1831

K.W.H. probable true value 1859

K.W.H. recorded by Thompson meter 2070

Therefore the Meter Constant $\frac{1859}{2070}$ .90

All wattmeter readings should be multiplied by .9. This seems to be the correct constant to use since the K.W.H. values check so closely in the first two cases above.

Cost of Coal per Kilowatt Hour

Coal consumed - - - - - - - - -	12.586 Tons	25,173 Lbs.
Ash - - - - - - - - - - - - - -	2.378 "	4,756 "
Combustible - - - - - - - - - -	10.207 "	20,414 "

Cost of Coal per ton, $1.10, per lb., .055¢

Probable true value K.W.H. Test No.1 is 1859

Pounds Coal per K.W.H. $\frac{25173}{1859} = 13.54$

Pounds of Comb. per K.W.H. 10.98

Cost of coal per K.W.H. at .055¢ per pound .745¢

Unit Efficiency

Test No.1.

Average K.W. Output - - - - - - -	195.8
" E.H.P. " - - - - - - - -	262
" I.H.P. - - - - - - - -	318
Unit Eff. at 39% Load - - - - - -	82.5%

Test No.2.

The second test was made on May 12, 1904 from 1:30 P M. to 6:30 P M. and was also run on a day of average operating conditi ons. The purpose of this test being to obtain the total output and input of power and to obtain data for calculating the unit efficiency.

The indicated horse power of the Russell Engine was obtained by two Crosby Indicators as in Test No.1 using an 80# spring. Cards and speed were taken every five minutes.

A one hour recording ammeter and a three hour recording voltmeter were put in the main circuit,thus doing away with the necessity of taking readings of the instruments every minute.

Both the Direct Current and the Alternating Current integrating wattmeters were read every ten minutes and an indicating wattmeter on the alternating current side was read every two minutes throughout the five hours.

From the charts of the recording instruments the average values of current and voltage for every ten minutes were found by means of a planimeter,the method being similar to the determination of mean effective pressure on indicator cards.

The same wattmeter correction, (.9) was used in this test as in test No.1.

A Weston indicating wattmeter was placed in the three phase circuit and readings taken every two minutes. These were used as a check on the Thompson integrating meter.

Curves of power consumption on the D.C. side and on the A.C. side are shown on plate No. XXII.

Curves of current, voltage, D.C. and A.C. kilowatts, total kilowatts, indicated horse power and speed are shown on plates Nos. XIX, XX and XXI.

Tables of calculated results for Test No. 2 are shown on plates Nos. X,XI,XII, and XIII.

Examples of indicator cards are on plates XIV and XV.

Two ammeter charts (a) and (b) and one voltmeter chart (c) are on plates XVI, XVII and XVIII.

Unit Efficiency, Test No.2

Average K.W. output, D.C.- - - - - -	-182.5	
" K.W. " A.C.- - - - - -	-108.0	
" K.W. " Total - - - - -	-290.5	
" E.H.P. " - - - - - - - -	-390	
" I.H.P Input - - - - - - - -	-466	
Unit Efficiency at 58% load	390 / 466	83.7%

CONCLUSIONS

Both tests being run under average operating conditions give a pretty good idea of the condition of efficiency and distribution. The plant was being operated on the battery of two Sterling boilers during Test No.1 when coal was weighed and considerable trouble was experienced from priming. At one time so much water had collected in the cylinder as to require a shut-down. The priming was probably due to dirty boilers.

The A.C.side of the system was not in operation when the first test was made, the load being entirely railroad and stationary motor loads. The peaks occur at intervals during the day when extra traffic is on the road, as at noon and about six o'clock. A peak is also noticeable when the interurban cars are at this end of the line. From the sample charts (a), (b) and (c) taken from the Bristol recording instruments, (a) shows a condition of as steady operating conditions as is usually obtained; (b) shows a widely fluctuating load which is more characteristic of the street railway conditions of such a small system. Chart (c) gives evidence of considerable variation of voltage and shows that it is not an easy thing to maintain a constant voltage with such a fluctuating load. The compounding does not seem to produce the desired effect of a rise in voltage with an increase of load althoug all series shunt was out. This faulty variation of voltage is easily seen in curves on plate XIX.

Probably the A.C. side disturbed the voltage to a considerable extent.

The speed regulation of unit was fairly good, the speed varied from 148 to 154 R.P.M. according to load, the normal speed being 150.

The cost of coal per K.W.H. was .745¢ and was obtained with Pana Screenings. This is a very hard coal to fire and contains about 18.9% ash.

The efficiencies vary about as one would expect, 82.5% at .39 full load and 83.7% at .58 full load.

TOTAL OUTPUT.

APR. 18, 1904.

TIME.	TOTAL AMPERES	STATION VOLTAGE	TOTAL KILOWATTS.
7-45	293	574	168
8-00	258	585	151
8-15	313	575	180
8-30	393	578	228
8-45	347	578	201
9-00	305	580	177
9-15	286	618	177
9-30	307	618	190
9-45	272	620	169
10-00	268	611	164
10-15	326	601	196
10-30	390	596	232
10-45	252	618	156
11-00	304	601	183
11-15	339	600	204
11-30	400	591	236
11-45	383	588	225
12-00	344	592	204
12-15	316	590	186
12-30	316	591	187
12-45	259	600	155
1-00	222	608	129

PLATE I.

TOTAL OUTPUT - CON.-

APR. 18, 1904.

TIME.	TOTAL AMPERES.	STATION VOLTAGE	TOTAL KILOWATTS.
1-15	272	598	163
1-30	330	586	193
1-45	322	588	189
2-00	332	583	194
2-15	358	585	209
2-30	400	588	235
2-45	269	600	162
3-00	258	608	174
3-15	315	588	186
3-30	383	588	225
3-45	340	585	199
4-00	326	583	190
4-15	322	585	188
4-30	322	595	191
4-45	280	592	166
5-00	270	589	159
AVERAGE	317	592	187.6

PLATE II.

POWER DISTRIBUTION.

APRIL 18, 1904.

TIME	FEEDER K.W.				
	WESTSIDE.	EAST SIDE	URBANA	D. U. G.	POWER.
7-45	26.9	56.9	21.8	20.7	34.4
8-00	32.2	49.8	18.2	17.0	35.1
8-15	13.2	86.2	19.0	16.1	43.1
8-30	19.1	50.9	61.7	58.9	47.9
8-45	22.6	47.4	43.4	44.0	54.3
9-00	23.2	37.7	34.2	31.3	56.2
9-15	17.3	41.6	34.0	37.0	63.1
9-30	20.4	32.7	44.5	48.8	63.7
9-45	14.9	31.6	40.3	42.1	62.6
10-00	42.2	41.0	27.0	29.4	61.1
10-15	12.6	44.5	52.9	51.1	60.6
10-30	20.9	71.5	48.4	44.8	63.8
10-45	13.6	21.0	34.0	34.6	62.5
11-00	40.9	39.1	28.9	28.2	54.7
11-15	13.2	59.5	39.0	40.8	57.6
11-30	18.9	43.2	60.8	62.7	57.3
11-45	17.6	23.5	71.7	74.0	59.4
12-00	17.7	62.7	44.4	38.5	57.5
12-0	20.1	86.1	26.6	26.0	32.5
12-30	20.7	39.0	50.8	40.2	23.7
12-45	13.2	32.4	39.0	39.6	24.0
1-00	16.4	23.7	29.8	31.6	27.4

PLATE III

POWER DISTRIBUTION – CONTINUED.

APRIL 18 1904.

TIME.	FEEDER K.W.				
	WEST SIDE.	EAST SIDE.	URBANA.	D.U.C.	POWER.
1-15	19.7	37.7	30.5	32.9	31.1
1-30	31.2	28.1	44.9	52.7	35.2
1-45	9.4	49.5	37.7	41.2	41.2
2-00	23.35	70.6	31.5	28.0	56.0
2-15	20.46	57.4	42.1	43.8	59.6
2-30	17.66	66.5	58.8	51.8	59.4
2-45	14.4	31.8	34.2	28.8	60.6
3-00	27.2	38.1	35.4	35.4	62.6
3-15	24.1	40.0	34.2	34.7	58.8
3-30	25.9	40.5	53.0	55.3	60.0
3-45	18.7	43.9	41.5	43.3	58.5
4-00	20.4	69.0	28.6	25.7	45.0
4-15	33.4	74.4	21.7	21.6	54.4
4-30	33.9	33.9	38.1	39.8	57.2
4-45	30.8	36.7	27.2	27.8	42.0
5-00	23.0	43.0	26.5	26.5	54.1
AVERAGE	21.8	46.9	38.1	38.1	50.9

PLATE IV.

GRAPHICAL REPRESENTATON OF POWER DISTRIBUTION.

APRIL 18, 1904.

WEST SIDE FEEDER.

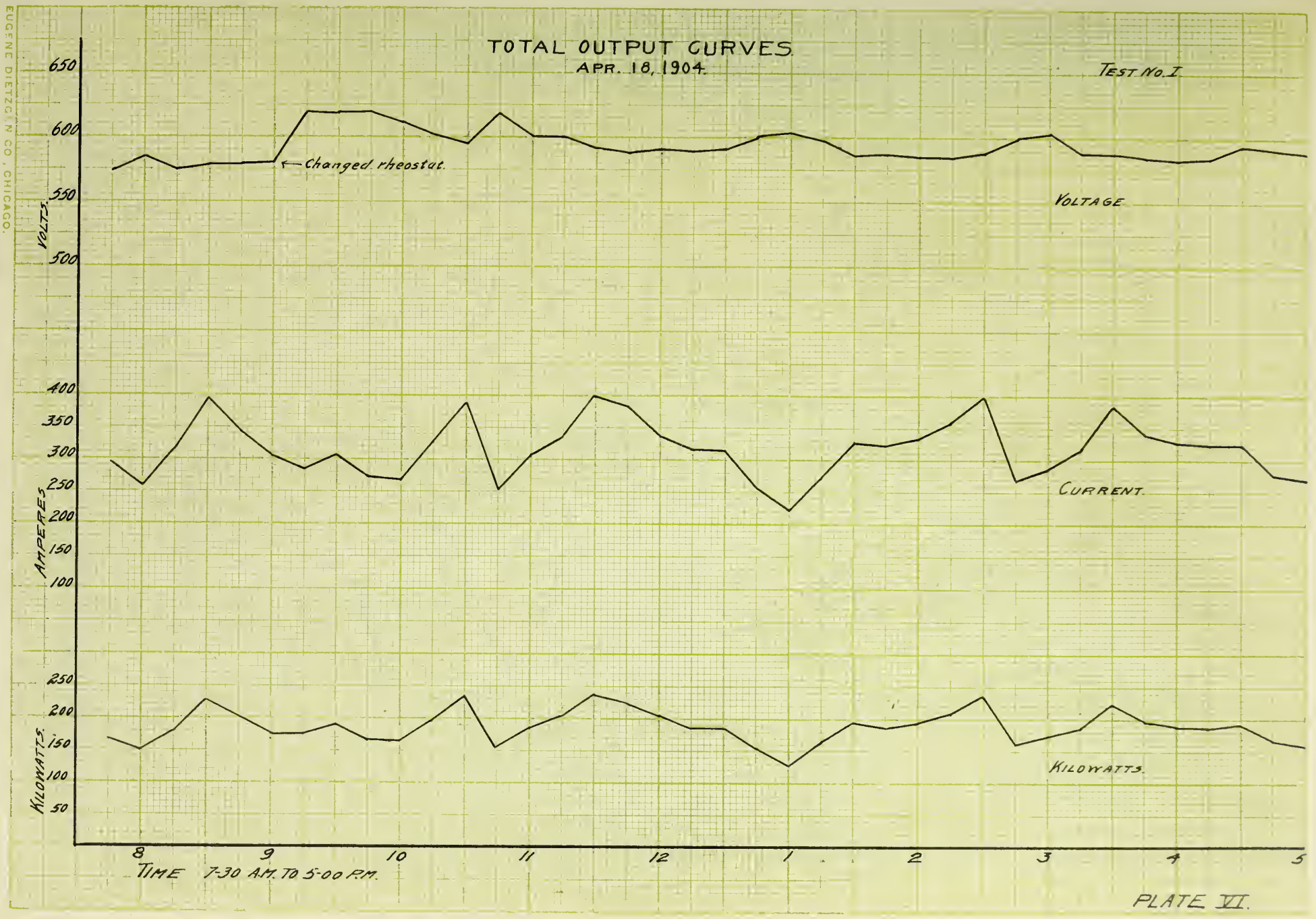
URBANA FEEDER.

D.U.C. FEEDER

EAST SIDE FEEDER

POWER FEEDER

PLATE V.


TOTAL OUTPUT CURVES.
APR. 18, 1904.
TEST NO. I
650
600
550
500
VOLTS.
← Changed rheostat.
VOLTAGE
400
350
300
250
200
150
100
AMPERES
CURRENT.
250
200
150
100
50
KILOWATTS.
KILOWATTS.
8
9
10
11
12
1
2
3
4
5
TIME 7-30 A.M. TO 5-00 P.M.
PLATE VI.

EUGENE DIETZGEN CO., CHICAGO.

FEEDER DISTRIBUTION. APR. 18, 1904. TEST NO. 1.

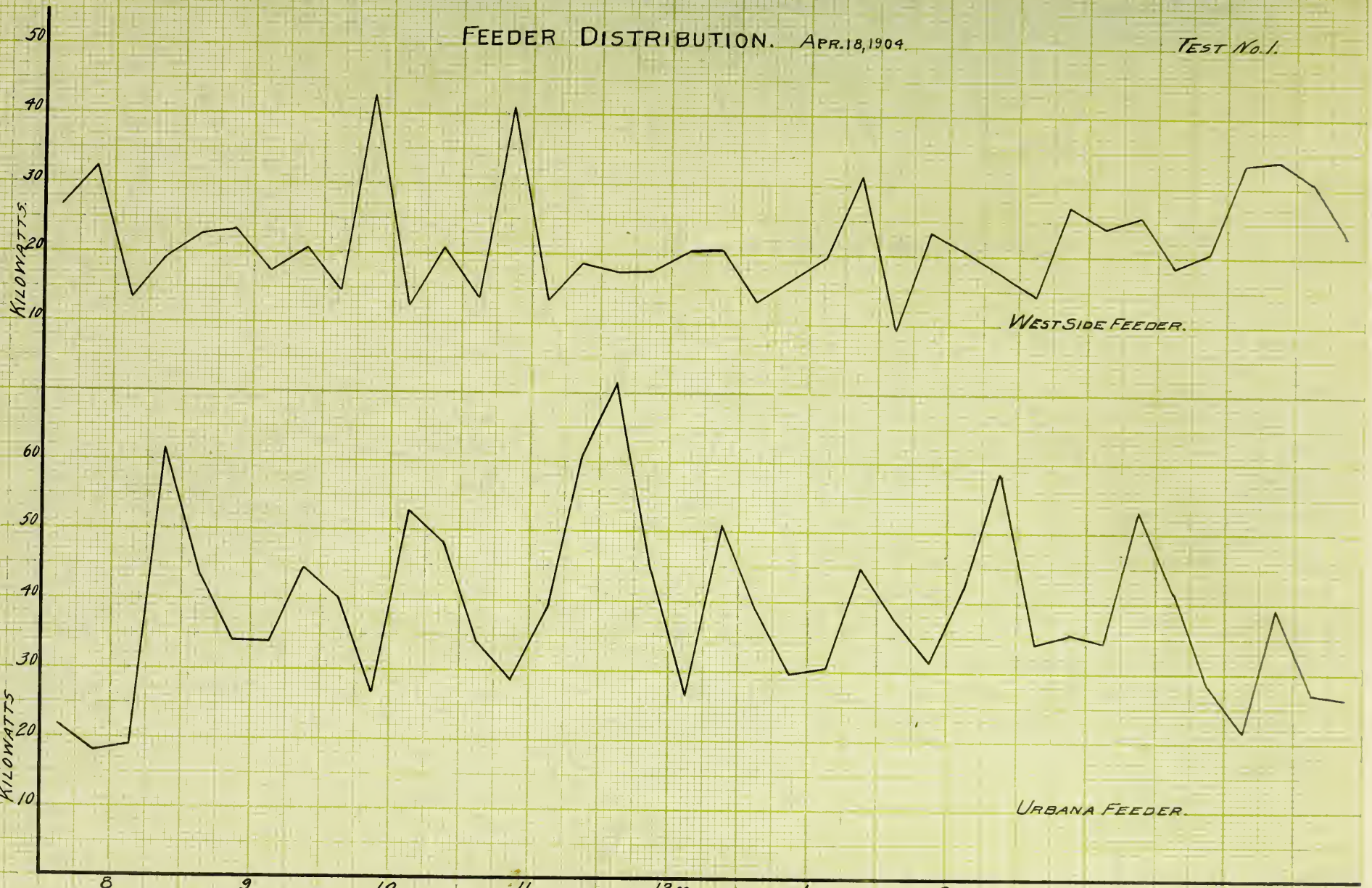
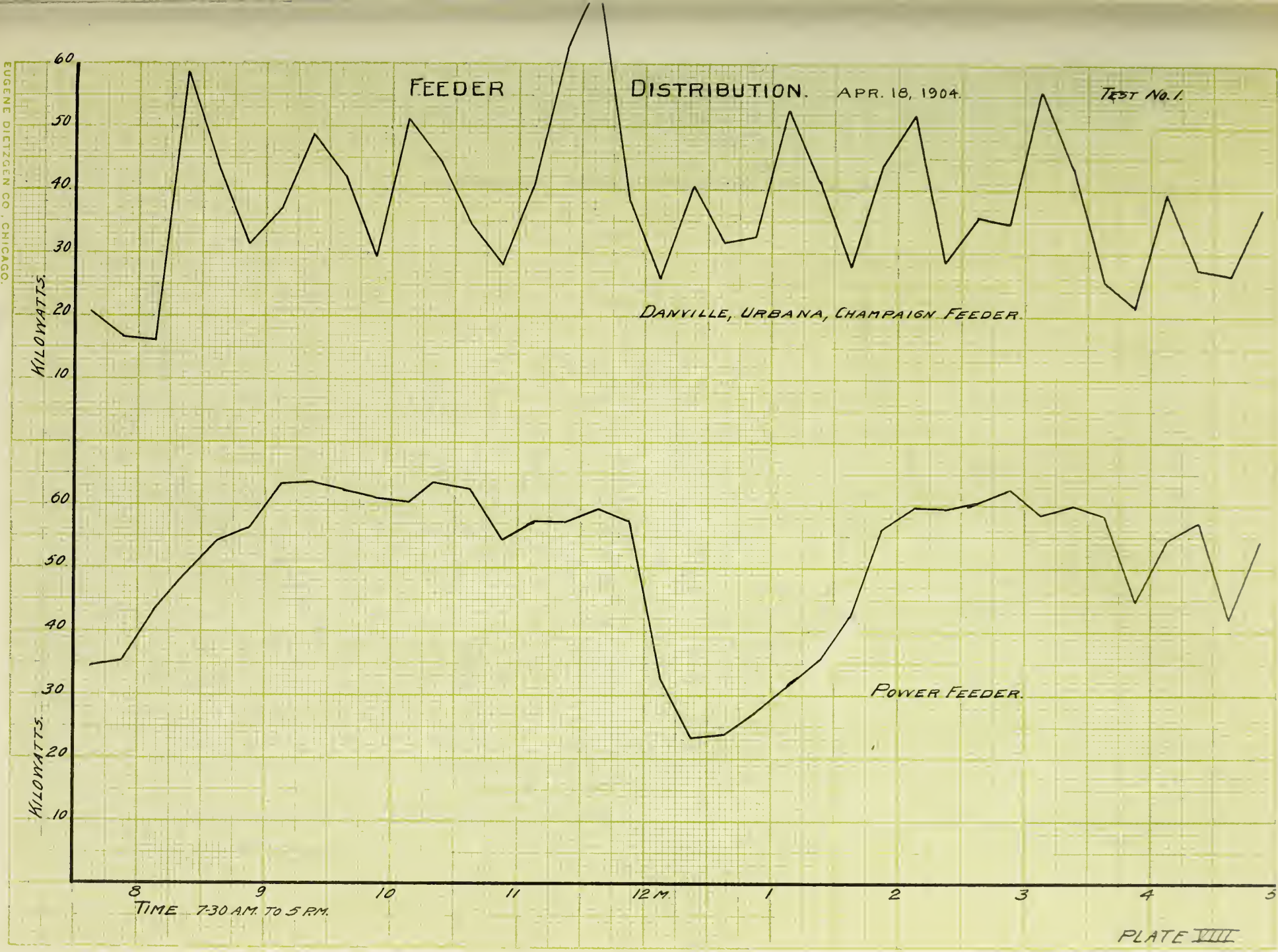


PLATE VII.


FEEDER DISTRIBUTION. APR. 18, 1904.
TEST NO. 1.
KILOWATTS.
60
50
40
30
20
10
DANVILLE, URBANA, CHAMPAIGN FEEDER.
KILOWATTS.
60
50
40
30
20
10
POWER FEEDER.
8
9
10
11
12 M.
1
2
3
4
5
TIME 7:30 A.M. TO 5 P.M.
PLATE VIII
EUGENE DIETZGEN CO., CHICAGO.

EUGENE DIETZGEN CO. CHICAGO.

FEEDER DISTRIBUTION. APR. 18, 1904. TEST. NO. 1.

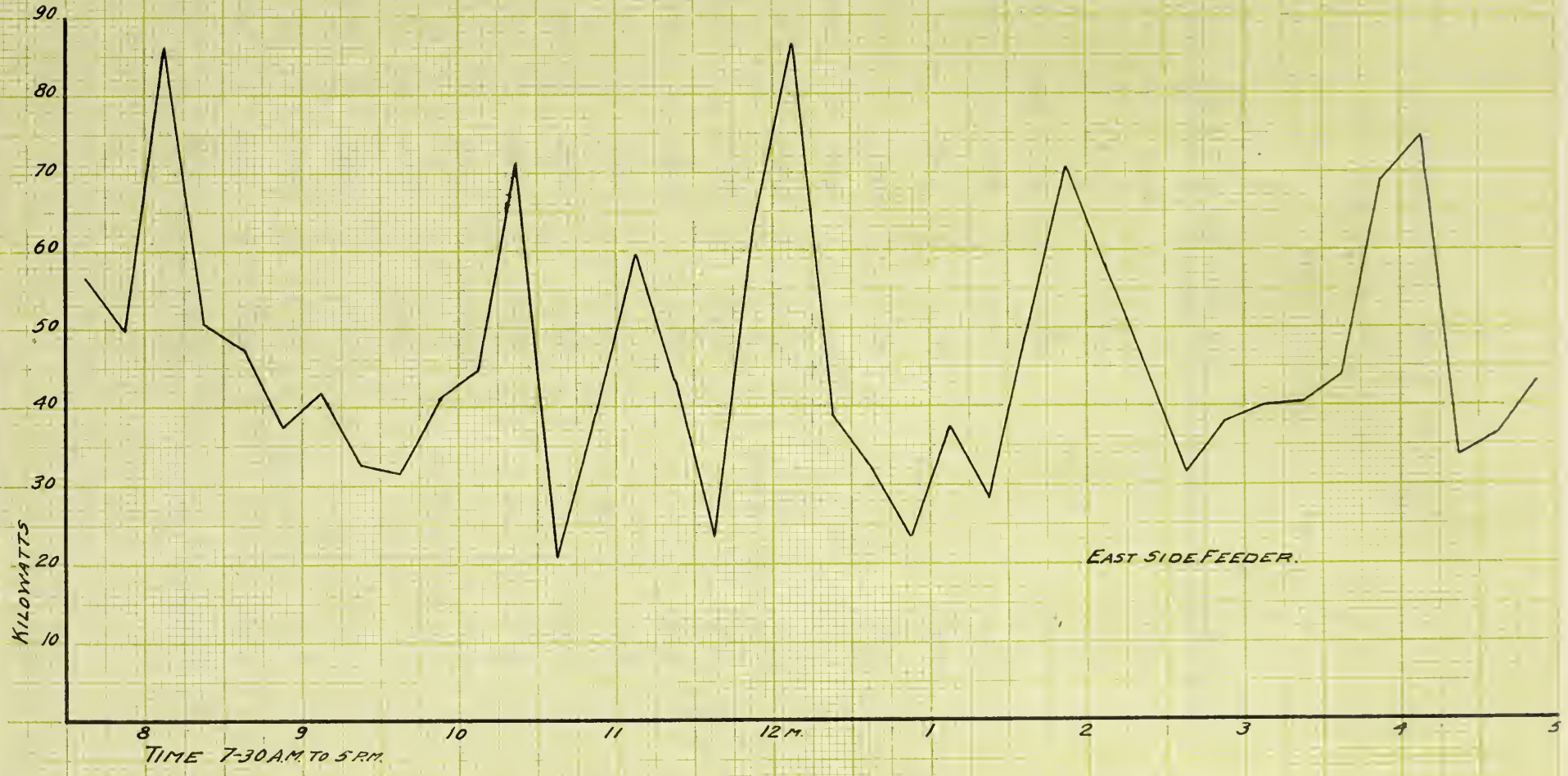


PLATE IX.

CURRENT. VOLTAGE. SPEED.
INDICATED H.P.

MAY 12, 1904.

TIME	AMPERES	VOLTS	I. H. P.	R. P. M.
1-30	390	570	492	148
1-40	385	574	542	148
1-50	350	592		150
2-00	300	594		151
2-10	425	570	440	148
2-20	365	573		149
2-30	375	592		150
2-40	350	592	488	150
2-50	260	597		151
3-00	325	599		151
3-10	425	571	574	149
3-20	390	575		148
3-30	415	587		148
3-40	350	576	518	150
3-50	315	580		148
4-00	300	583		149
4-10	288	596	456	150
4-20	330	599		148
4-30	335	586		152

PLATE X.

CURRENT VOLTAGE SPEED - CON -

INDICATED H.P.

MAY 12, 1904.

TIME	AMPERES.	VOLTS.	I.H.P.	R.P.M.
4-40	310	591	486	150
4-50	280	588		149
5-00	265	584		151
5-10	310	586	464	150
5-20	280	587		150
5-30	290	580		150
5-40	330	591	451	150
5-50	345	580		150
6-00	310	597		150
6-10	335	573	406	150
6-20	350	600		150
6-30	310	589		150

PLATE XI.

POWER CONSUMPTION.

MAY 12, 1904.

TIME.	KILOWATTS.			KILOWATTHOURS.		
	D.C.	A.C.	TOTAL	D.C.	A.C.	TOTAL
1-30PM.	0	0	0	0	0	0
1-40	180	138	318	30	30	60
1-50	240	99	339	70	40	110
2-00	150	85	235	95	55	150
2-10	270	68	338	140	70	210
2-20	180	56	236	170	80	250
2-30	300	83	383	220	100	320
2-40	150	83	233	245	105	350
2-50	150	115	365	270	125	395
3-00	180	94	274	300	140	440
3-10	270	119	389	345	170	515
3-20	210	132	342	380	190	570
3-30	360	104	464	440	210	650
3-40	180	120	300	470	230	700
3-50	180	138	318	500	240	740
4-00	180	132	312	530	260	790
4-10	210	99	309	565	280	845
4-20	210	98	308	600	300	900
4-30	240	106	346	640	320	960
4-40	180	111	391	670	330	1000
4-50	180	147	327	700	355	1055

PLATE XII.

POWER CONSUMPTION. - CONTINUED. -

MAY 12, 1904.

TIME.	KILOWATTS.			KILOWATTHOURS.		
	D.C.	A.C.	TOTAL	D.C.	A.C.	TOTAL
5-00	180	101	281	730	380	1110
5-10	180	156	336	760	410	1170
5-20	180	153	333	790	430	1220
5-30	180	117	297	820	450	1270
5-40	180	148	328	850	470	1320
5-50	180	106	286	880	490	1370
6-00	240	78	318	920	500	1420
6-10	180	70	250	950	510	1460
6-20	180	74	254	980	530	1510
6-30	210	67	277	1015	540	1555

PLATE XIII.

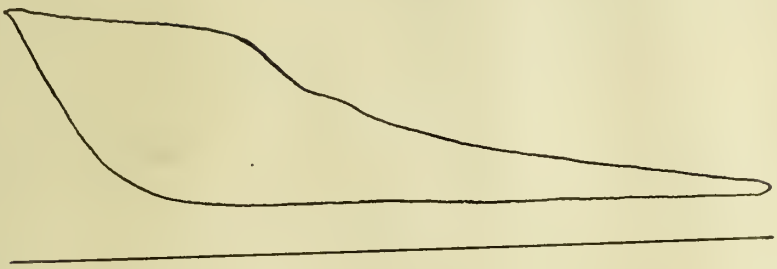
10-03-2000-R

Engine Russell
Cylinder 30"X30".
End Head.
Scale 80.

UNIVERSITY OF ILLINOIS
MECHANICAL ENGINEERING DEPARTMENT
DIAGRAM TAKEN AT Champaign
Railway Power PLANT.

Date May 12 1904.
Time 3-30 P.M.
R. P. M. 148.
Observer Wehmeier.
H.P. 271

Crosby 2-inch Drum



10-03-2000-R

Engine Russell
Cylinder 30"X30"
End Crank
Scale 80

UNIVERSITY OF ILLINOIS
MECHANICAL ENGINEERING DEPARTMENT
DIAGRAM TAKEN AT Champaign
Railway Power PLANT

Date May 12, 1904.
Time 3-30 P.M.
R. P. M. 148.
Observer Wehmeier.
H.P. 305

Crosby 2-inch Drum

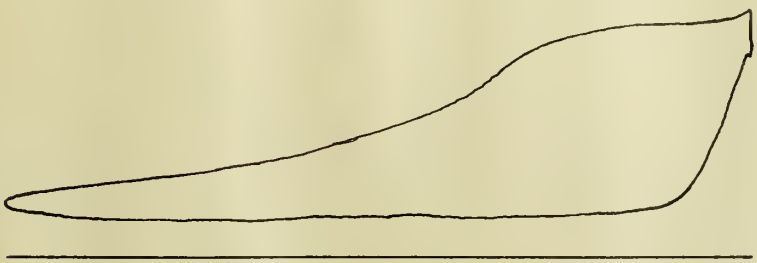


PLATE XIV.

10-03-2000-R

Engine RUSSELL
Cylinder 30"X30"
End HEAD.
Scale 80.

UNIVERSITY OF ILLINOIS
MECHANICAL ENGINEERING DEPARTMENT
DIAGRAM TAKEN AT CHAMPAIGN
RAILWAY POWER PLANT.

Date MAY 12, 1904.
Time 3-35 P.M.
R. P. M. 150
Observer WEHMEIER
H.P. 157

Crosby 2-inch Drum

10-03-2000-R

Engine RUSSELL
Cylinder 30"X30"
End CRANK
Scale 80

UNIVERSITY OF ILLINOIS
MECHANICAL ENGINEERING DEPARTMENT
DIAGRAM TAKEN AT CHAMPAIGN
RAILWAY POWER PLANT.

Date MAY 12, 1904.
Time 3-35 P.M.
R. P. M. 150
Observer WEHMEIER
H.P. 149.

Crosby 2-inch Drum

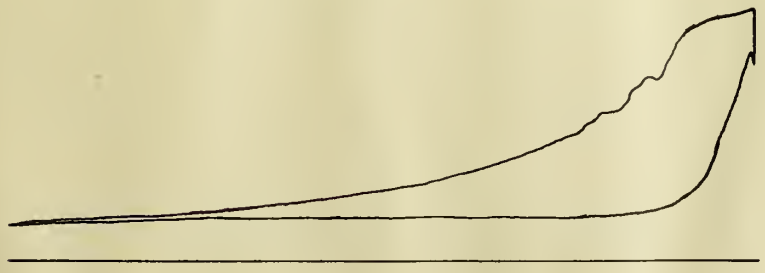


PLATE XV.

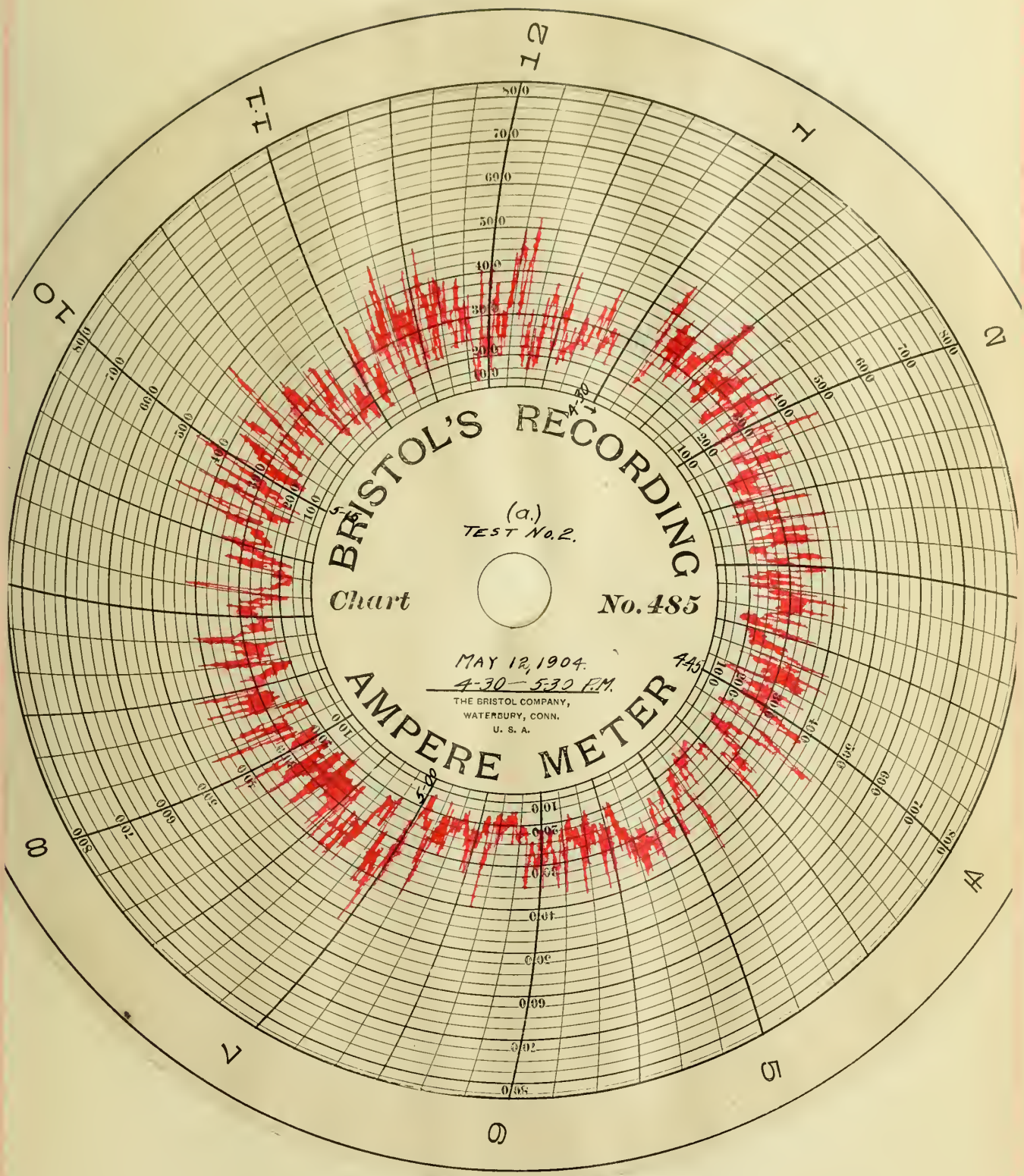

BRISTOL'S RECORDING
(a.)
TEST No. 2.
Chart
No. 485
MAY 12, 1904.
4-30 — 5-30 P.M.
THE BRISTOL COMPANY,
WATERBURY, CONN.
U. S. A.
AMPERE METER
12
1
2
3
4
5
6
7
8
9
10
11

PLATE XVI.

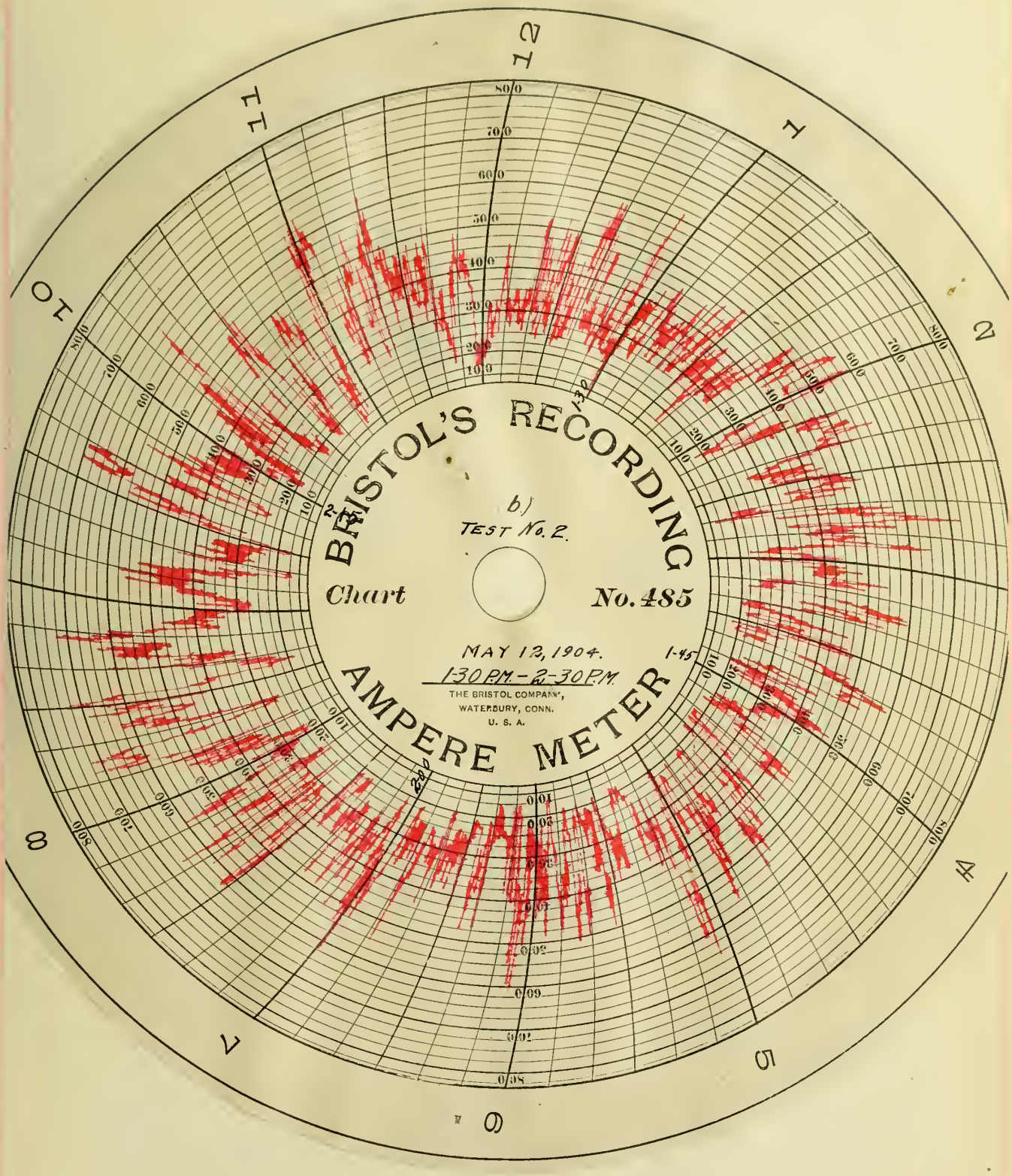

BRISTOL'S RECORDING
AMPERE METER
b)
TEST No. 2.
Chart
No. 485
MAY 12, 1904.
1-30 P.M. - 2-30 P.M.
THE BRISTOL COMPANY,
WATERBURY, CONN.
U. S. A.
12
1
2
3
4
5
6
7
8
9
10
11

PLATE XVII.

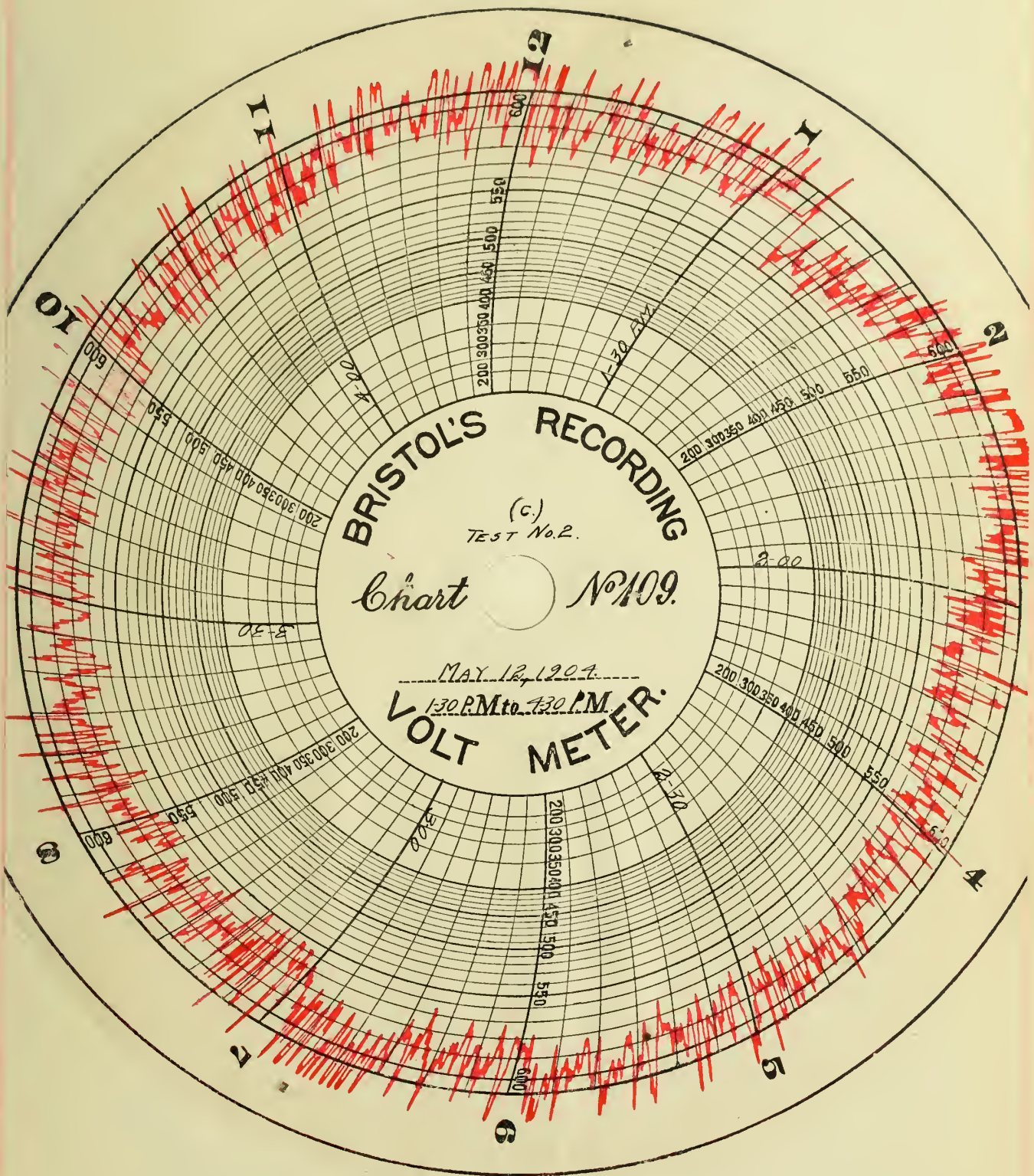
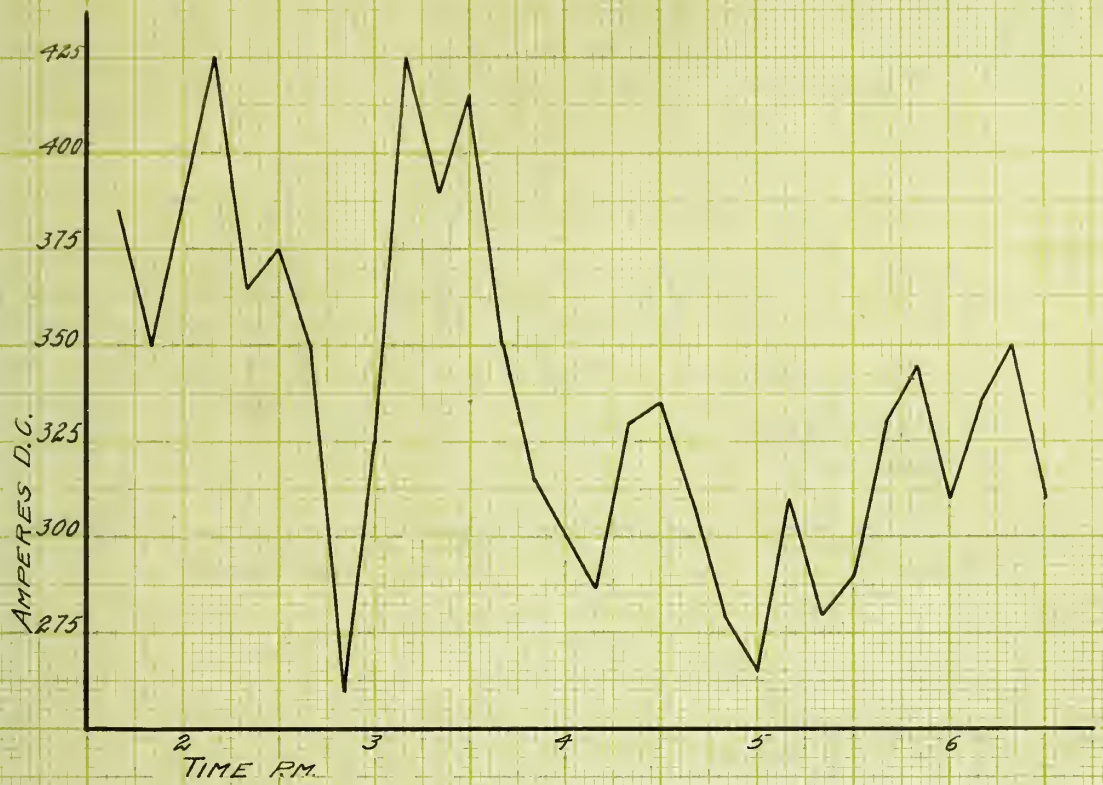

BRISTOL'S RECORDING
(C.)
TEST No. 2.
Chart No 109.
MAY 18, 1904.
1-30 P.M. to 4-30 P.M.
VOLT METER.
12
1
2
3
4
5
6
7
8
9
10
11
200 300 350 400 450 500 550 600

PLATE XVIII.

DIRECT CURRENT VOLTAGE AND AMPERE CURVES.

TEST No. 2.

MAY 12, 1904.



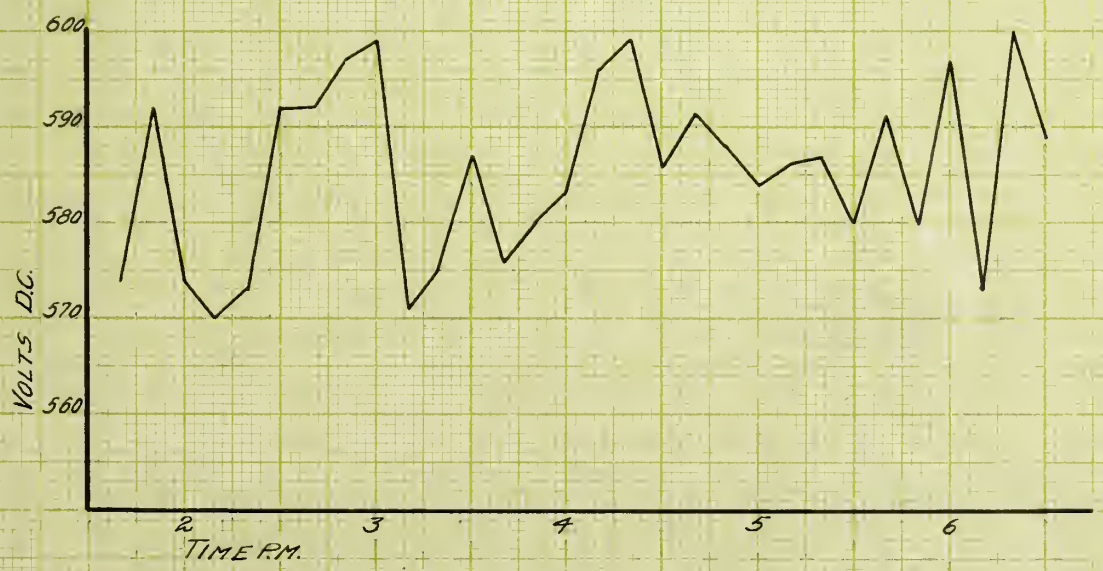
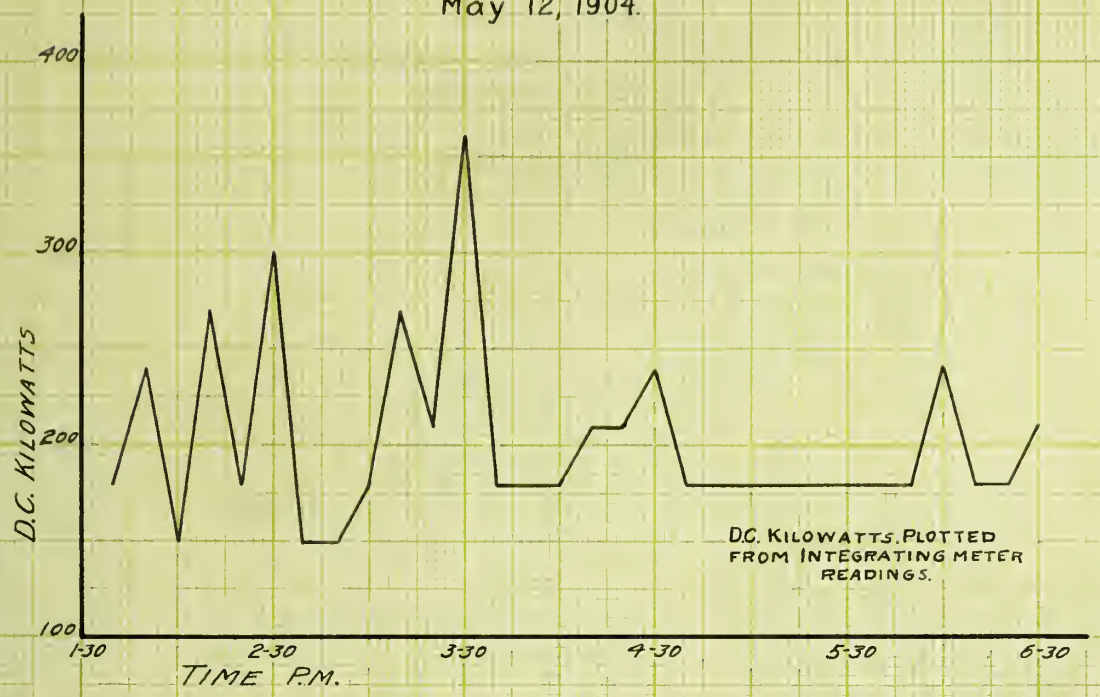


PLATE XIX.

EUGENE DIETZGEN CO., CHICAGO.

CURVES SHOWING RATE OF CONSUMPTION. TEST No. 2.

May 12, 1904.



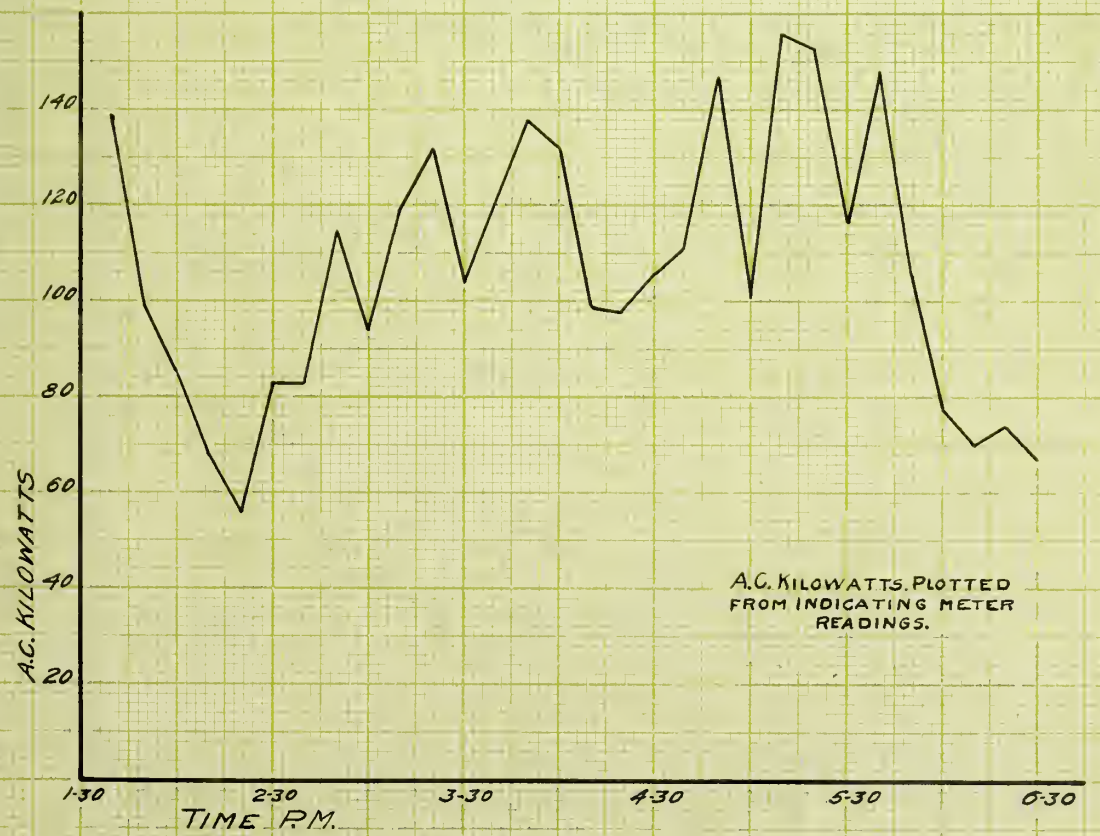


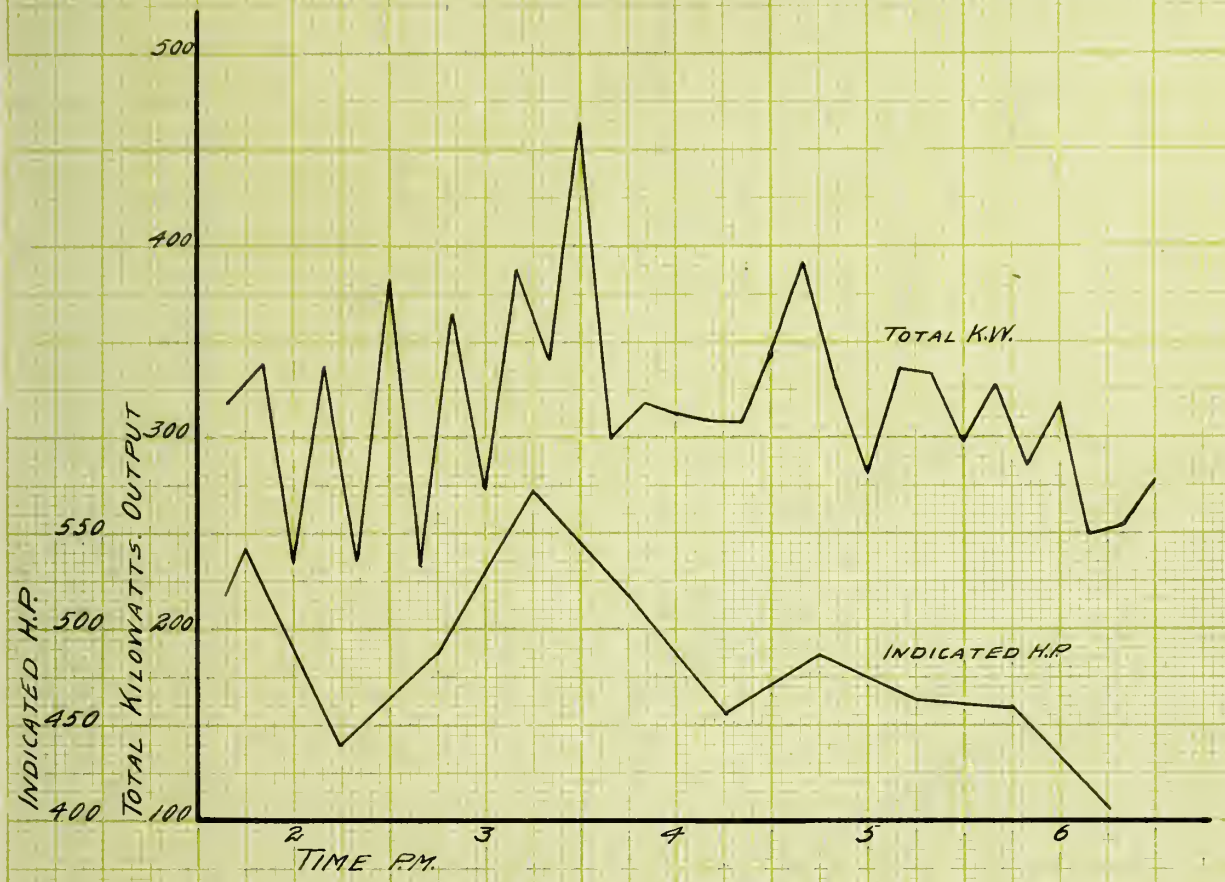
PLATE XX.

EUGENE DIETZGEN CO., CHICAGO

INDICATED H.P.
TOTAL OUTPUT AND
SPEED CURVES.

MAY 12, 1904.

TEST No. 2.



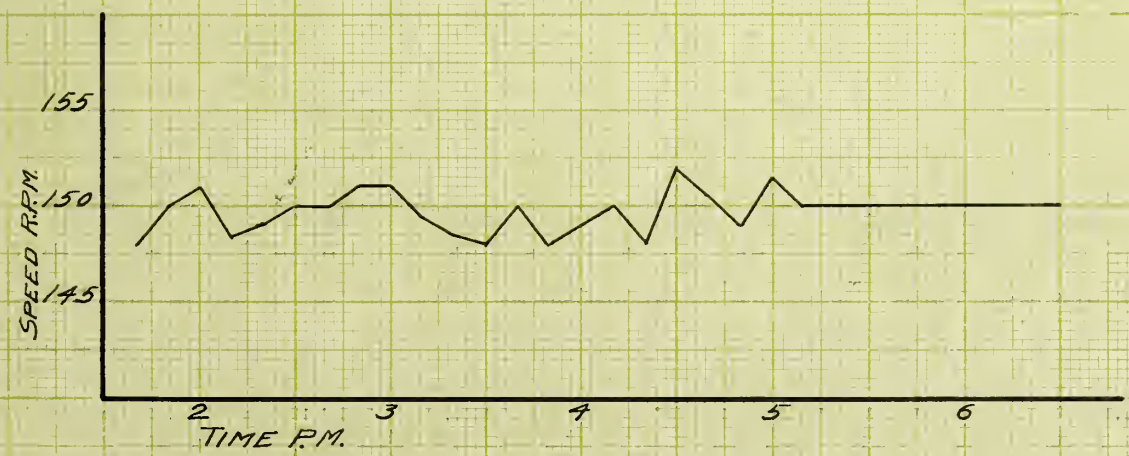


PLATE XXI.

EUGENE DIETZGEN CO., CHICAGO.

CONSUMPTION CURVES.

TEST No. 8.

May 12, 1904.

Plotted from Integrating Wattmeter Readings.

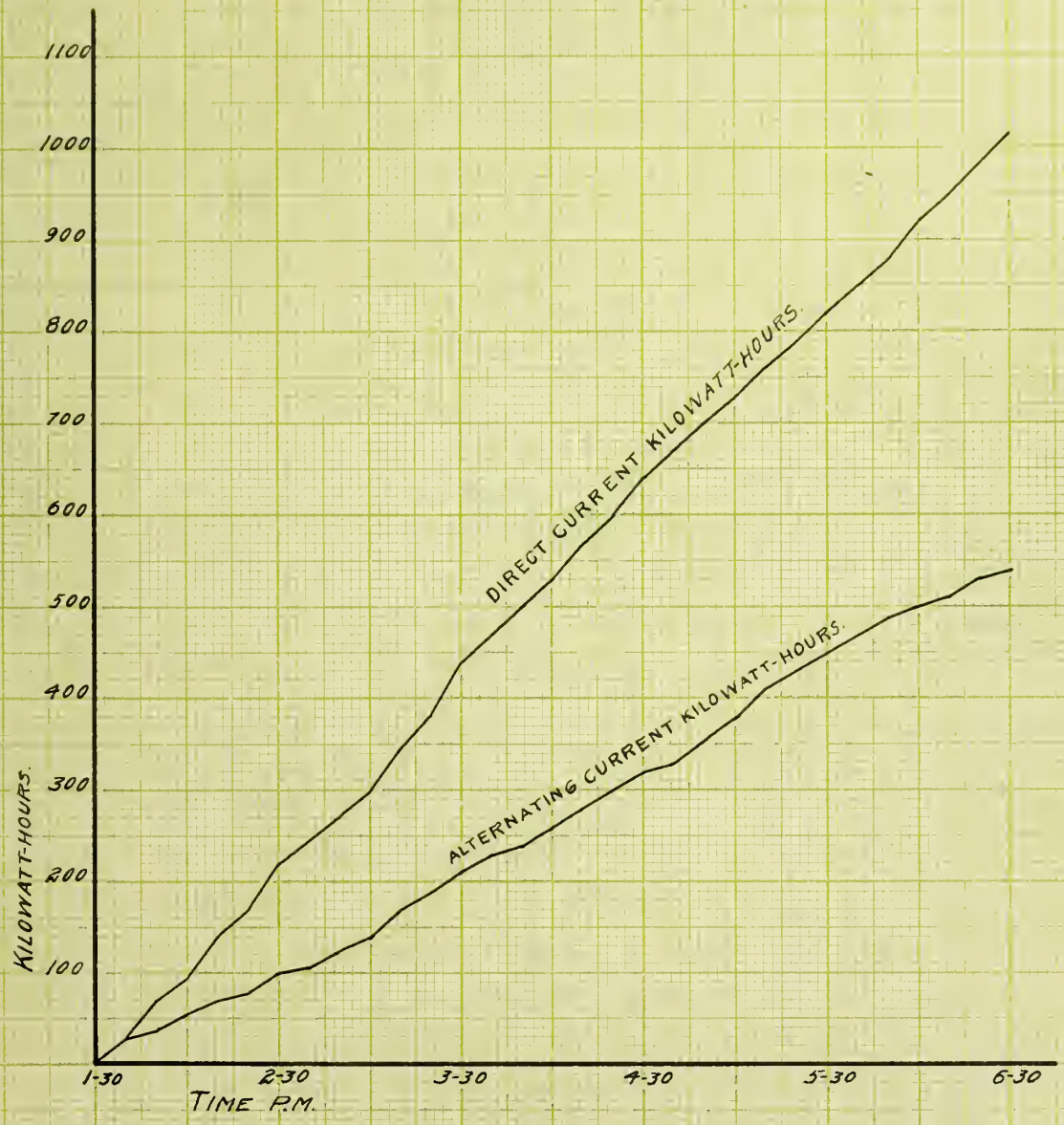


PLATE XXII.

EUGENE DIETZGEN CO., CHICAGO.

UNIVERSITY OF ILLINOIS-URBANA
3 0112 086763148